RESEARCH ARTICLE

Transient stability Studies of series FACT Device: A Comparative Study of GCSC and TSSC

M. Santhosh Raikar, G.D.Kamalapur

Department of Electrical and Electronics Engineering, Sri Dharmasthala Manjunatheshwara College of Engineering and Technology, Dharwad, 580002, India

ABSTRACT: Today's power system continues to expand exponentially due to extensive automated need for both domestic and industrial needs. The expansion of power transmission networks is limited due to environmental right of way and economic reasons. The ever growing demand of power system network has resulted in rotor angle oscillations and voltage instability. It is precisely due to the inability to generate the required reactive power and real power control that propounds the cause of voltage collapse and rotor oscillations. Therefore it is time to focus on the use of the shunt reactive compensation devices to alleviate this issue of voltage stability and series reactive compensation devices to improve the rotor angle stability. Flexible AC Transmission Systems (FACTS), which have recently been developed in power electronics, can make it easier to control the flow of power, boost power transfer capabilities, lower the cost of generating, improve security, and enhance the stability of power systems. The growth of large interconnected power systems demands faster response to maintain stability. Therefore it is also necessary to develop computationally intelligent controllers based FACTS devices for faster and more accurate control action. The objective of this paper is to analyses stability enhancements in power system networks by FACTS devices like GCSC and TSSC. In this work small signal stability and transient stability analysis of the above FACTS devices are investigated. From the analysis it is proved that TSSC is the best FACTS device for transient stability enhancements.

KEYWORDS: Thermal Stability, TSSC, GCSC, FACT

https://doi.org/10.29294/IJASE.9.2.2022.2698-2708 **©2022 Mahendrapublications.com, All rights reserved**

INTRODUCTION

The generator rotor is provided with damper windings to dampen the amplitude of oscillations. Fast excitation systems were then implemented to enhance the generators' reaction and maintain synchronism, although this decreased the oscillations' damping. Therefore, it was common practice to dampen these oscillations using excitation systems with Power System Stabilizers (PSS). In order to increase the reliability of the power supply and for economic reasons, the power stations were heavily interconnected during the 1960s. But these interconnections resulted in low-frequency oscillations (0.1-1 Hz) in which the generators of one area swing against the generators of neighboring areas. These low frequency oscillations prevented further development of highly interconnected networks. Since 1960s numerous theoretical studies and field tests have been conducted by power engineers regarding the stability issues [1-2]. According to the nature of power system oscillations, controllers are developed to increase the damping torque. The damping of power oscillations is possible by using power system stabilizers and FACTS devices. Power system stabilizers are incorporated in generator excitation systems and are used to damp the generator electro-mechanical oscillations by taking generator speed and electrical power as inputs. Whereas the FACTS devices are installed in transmission systems away from the generation systems is to damp the generator electro-mechanical oscillations. The electric power generated by the generators is consumed by the loads at the consumer side through the transmission system. The transmission lines are operated below their thermal ratings to ensure reliability of electric supply to the loads. There is a huge increase in power demand in recent years due to industrialization and urbanization. Therefore the transmission system capacity is to be increased [3-5]. Due to high investment costs and factors like time taken for construction and disruption of existing power systems, the installation of new transmission lines becomes difficult. Therefore it becomes necessary to utilize the existing transmission

**Corresponding Author: santhuee020@gmail.com*

Received: 18.08.2022 **Accepted:** 05.10.2022 **Published on**: 01.11.2022

lines to the maximum capacity. FACTS can efficiently utilize the existing transmission to improve voltage stability of the bus and also damps the low frequency oscillations. The objective of FACTS controllers is to control the power flow in the transmission lines and to increase the transmission system reliability and security. The rapid development of modern power electronics technology has led to a number of FACTS controllers like GCSC and TSSC. Thus with marginal investment for FACTS device installation compared to new transmission line installations, it is possible to achieve increased power transmission within short period of time. Thus the FACTS devices installation in transmission system results in transmission line installation cost reduction, increase in transmission line power transfer capacity and increase in stability, security and reliability of power systems [6].

PROBLEM STATEMENT

The rapid increase in electric power demand led to the burden over the electrical network resulting the different types of problems in the network. Therefore, enhancement of power system stability is the ultimate requirement. The ever growing demand of power system network has resulted in rotor angle oscillations and voltage instability. It is precisely due to the inability to generate the required reactive power and real power control that propounds the cause of voltage collapse and rotor oscillations. For improving the stability, different types of FACTS devices have been used. Various studies have been done in the field of power system design, modeling, operation, control, and application of FACTS devices. The detailed studies of several FACTS devices are strongly needed. This is because the operation a FACTS device affects the multiple conditions (contingencies, equipment failure, faults, sustained oscillations, etc.) occurring on a power system. Flexible AC Transmission Systems (FACTS), which can facilitate the control of power flow, increase the power transfer capability, decrease the generation cost, improve the security and enhance the stability of power systems.

METHODOLOGY

The methodology deals with power angle curve variations in the SMIB system with various FACTS devices for the investigation of system and thus improves the dynamic stability of the power system. FACTS devices can transient stability and small signal stability. For analysis, a basic SMIB system is taken into account. The SMIB system is apply to the FACTS devices, such as TSSC and GCSC. Different FACTS devices are used to identify the systems' Eigen values. Numerous inferences are seen and observed based on the Eigen values. The two scenarios mentioned above are investigated for TSSC and GCSC to improve power system's small signal stability. The conclusions reached showed that various FACTS devices led to various steady-state rotor angles and various rotor oscillation frequencies. If the rotor angle changes by just 10 degrees, the rotor oscillations alter until the rotor reaches its steady state value, and the accompanying changes in the There is evidence of oscillation frequency. In the second instance, a 0.2 pu change in power input is specified as a disturbance, leading to the observation of rotor oscillations and associated frequency oscillations.

In both cases all FACTS devices result different system matrices and Eigen values as a result of all FACTS devices. The results received vary from one FACTS device to another. All of the cases are thoroughly discussed along with various stability parameters, such as the maximum power that can be used, the steady state rotor angle, the synchronizing coefficient, the oscillation frequency of the rotor, the damping ratio, the damped frequency of the oscillations, the response time constant, the system matrix, and the Eigen values. As a result, the analysis of tiny signal and transient stability of various FACTS devices integrated into the SMIB system is performed, and various conclusions are addressed based on the results. The SMIB system's power angle curve variations are tested both with and without FACTS devices. The small signal stability is then tested both the case with and without FACTS devices. The transient stability analysis is then performed both with and without FACTS devices.

4. Transient Stability Analysis Using Equal Area Criterion

When a machine is subjected to a significant disturbance, such as the sudden application of a heavy load, the loss of generation, the loss of a heavy load, or a system fault, transient stability studies are used to determine whether or not synchronism is maintained. Large disturbances

cause oscillations of such size that the nonlinear swing equation cannot be linearized and must instead be solved. For the purpose of predicting stability for significant disturbances, the Equal area criterion is applied. This approach relies on a graphical representation of the energy contained in the rotating mass to assess the machine's stability following significant disturbance. The following is the swing equation:

$H/\pi fo.d^2\delta/dt^2=Pm-Pe=Po$ (4.1)

Where Pa is the accelerating power, H inertia constant, fo initial frequency, Pm mechanical input power, Pe electrical output power therefore the above equation is rewritten as follows

$d^2\ \delta\ /dt^2=\pi fo/H.(Pm-Pe)$ (4.2)

Pm –mechanical input ,H- inertia constant ,

d δ/dt change in rotor angle with respect to time

The above equation after simulation results as follows

$$d\ \delta/dt=\sqrt{\frac{2\pi fo}{H}.\int_{\delta 0}^{\delta} Pm-Pe}\, d\ \delta \quad (4.3)$$

The above equation gives the relative speed of the machine concerning the synchronously revolving reference frame for stability this speed must become zero at some time after disturbance .therefore from the above equation, for stability criteria the following equations are true

$$\int_{\delta o}^{\delta} Pm-Pe\ d\ \delta=0 \quad (4.4.)$$

A machine with initial operating angle $\delta o$is considered for which the corresponding mechanical power input Pmo=Peo when there is a Sudden step increase in input power to Pm1 since Pm1>Peo the rotor starts accelerating and the power angle δ increase the excess energy stored in the rotor during initial accelerating is as follows

$$\int_{\delta o}^{\delta} Pm1-Pe\ d\ \delta$$

=area abc=area A1 (4.5) Then the energy stored in the rotor is given up and therefore it decelerated back to synchronous speed is given by

$$\int_{\delta 1}^{\delta max} Pm-Pe\ d\ \delta$$ =area bdc=area A2 (4.6)

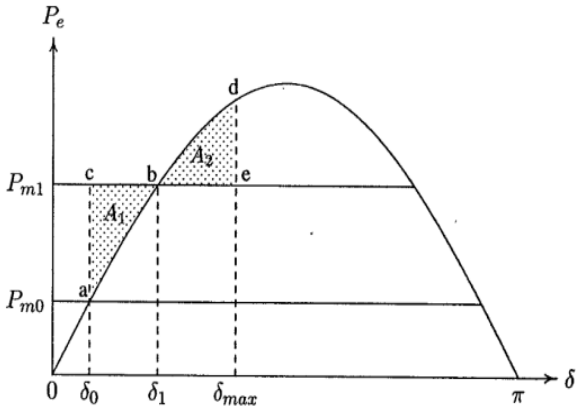

Fig.1: Equal area criteria for sudden change in load

A. *Equal area criterion for sudden change in load and three-phase fault*

The damping contained in the machine will reduce these oscillations, and a new steady state rotor angle is 1 is reached (Fig.1). The rotor swings at point b between points a and d which is δmax. The rotor angle oscillates back and forth between is δo and δmax at its natural frequency. This is referred to as the equal area criteria. Two different situations are used in the transient stability analysis. 1. Use in response to an abrupt increase in power input 2. Use with a three-phase fault.

B. *Application to sudden increase in power input*

The equal area criteria is used to determine the maximum additional power Pm which can be applied to maintain stability for a sudden change in power in power input the stability is maintained only if area A2 is less than or at least equal to area A1 as shown in Fig.2 the is δmax is marked for reference in Fig.2 applying the equal

area criteria and simplifying the equation the following expression is obtained:

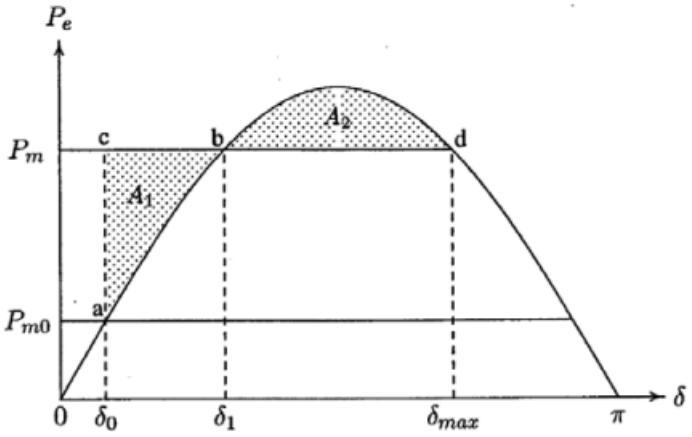

Fig.2: Equal area criterion maximum power limit

(δmax- is δo)sin δmax+cosδmax=cosδo (4.7)

The above nonlinear algebraic equation can be solved by iterative technique for δmax using netons raphson method once δmax is obtained the maximum permissible power or transient stability limit can be found from Pm=Pmaxsin δ1 (4.8)

δ1=π- δmax (4.9) critical angle change with respect to change in power.

5. RESULTS AND DISCUSSION

Small signal stability analysis and transient stability will discuss in the result part. Table 1 shows a small signal stability analysis of TSSC and GCSC, based on Eigen value and the system matrix stability of system will be verified.

Table 1: Results obtained for small signal stability analysis with different FACTS devices

Parameter	GCSC (a=0.30%)	TSSC (X=0.65)
Pmax	1.1700pu	1.5385pu
do	0.5385rad	0.4006rad
Do_deg		
Ps	1.0044pu	1.4166pu
Wn	4.3634rad	5.1831rad
Z	0.2998pu	0.2525pu
Wd	4.1636 rad	5.0152 rad
fd	0.6627	0.7982
Tau	0.7643	0.7643
th	1.3561	1.4056
A= system matrix	0 1.0000 - 37.7061 -2.6169	0 1.0000 -62.3161 - 2.6169
K=eign value	-1.3085 + 5.9995i - 1.3085 - 5.9995i	-1.3085 + 7.7849i - 1.3085 - 7.7849i

The eigen values of A has a negative real part for both cases and therefore lie on the left half of the complex plane, hence the system is stable. In both, the cases the damping remains the same as the negative real part of the Eigen values are same whereas there is a slight increase in the frequency of oscillations for TCPAR-based SMIB. Thus the TCPAR improves

the system stability by increasing the synchronizing power constant and thereby reducing the power angle, δ. The various values obtained are shown in Table 1.

A Case study for Transient stability analysis

5.1.1 Case 01 Sudden Increase in power input with FACTS device

Sudden Increase in power input with GCSC (Pmo =0.6)

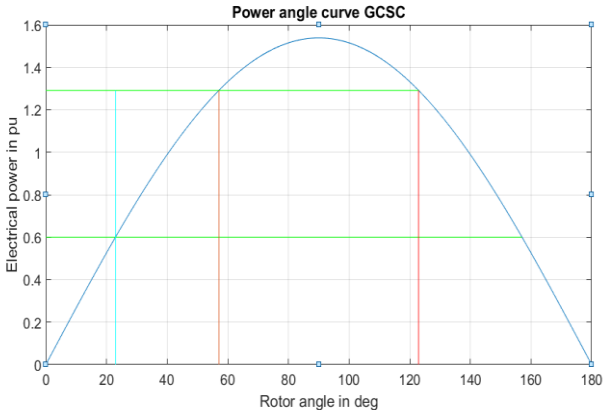

Fig.3 MATLAB plot of equal area criterion with GCSC for a sudden change in load

With GCSC connected to it, the SMIB system under consideration is impacted by a sudden shift in power input. According to the equal area criterion curves plotted in MATLAB as shown in Fig.3, the mechanical power input should not be greater than 1.977 pu, which is referred to as the total power of critical stability, for a machine operating with an initial power input of Pm = 0.6 pu and an initial operating angle of 15.466 degrees. The sudden maximum additional power that can be applied is 1.210 pu. A new operating angle of 53.540^0 is then reached. The rotor will lose synchronism and become unstable if the maximum swing angle is greater than 126.460^0 degrees. For the rotor to lose synchronism and which leads to an unstable condition. Thus it is inferred that to maintain stability the sudden increase in power input should be less than the maximum limit otherwise which results in a loss of synchronism with the infinite bus. And thus an additional sudden power input of 0.293 pu can be given for the SMIB system with GCSC. There is a increase in the maximum angle of swing from 125.840^o to 126.460. Thus it is clear that GCSC improves the transient stability of the system by increasing the transient stability margin.

Case 2 Sudden Increase in power input with TSSC (Pmo = 0.6):

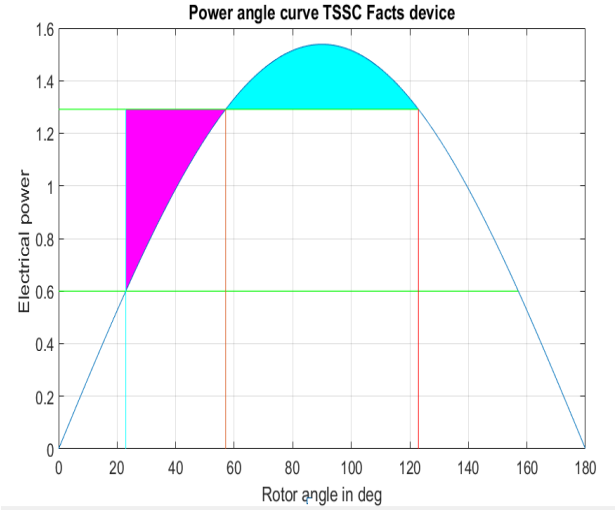

Fig.4: MATLAB plot of equal area criterion with TSSC for sudden change in load

The SMIB system considered is subjected to the sudden change in power input with TSSC connected to it. From the equal area criterion curves plotted in MATLAB as shown in Fig.4, it is observed that for a machine operating with an initial power input of Pm = 0.6 pu, initial

operating angle = 12.840 degrees, the sudden maximum additional power that can be applied is 1.537pu that is the mechanical power input should not exceed 1.6 pu, which is called as the total power of critical stability. Then it settles at a new operating angle δ= 52.317 The rotor will lose synchronism and become unstable if the maximum swing angle is greater than 127.68^0 Thus, it can be concluded that to retain stability, a rapid increase in power input must be greater than the maximum allowable value; otherwise, synchronism with the infinite bus is lost. The Table 2 compares the parameters of the SMIB transient stability system with and without TSSC, and it is clear from this comparison that the SMIB with TSSC increases the transient stability margin by decreasing the initial power angle by margin by increase the initial power angle by 1.537. It is also observed that sudden additional power with TSSC is increase from 1.084 pu to 1.537 p.u. and thus an additional sudden power input of 0.235 pu can be given for the SMIB system with TSSC There is a increase in maximum angle of swing from 125.840^o to 127.68 deg. Thus it is clear that TSSC improves the transient stability of the system by increasing the transient stability margin.

Table 2: Results obtained for Transient stability analysis (Sudden Change in load) with different FACTS devices

PARAMETER	No FACTS DEVICE	WITH GCSC	WITH TSSC
Initial power	0.600pu	0.60pu	0.600pu
Initial power angle	16.791^0	15.466^0	12.840^0
Sudden additional power	1.084pu	1.210pu	1.537pu
Total power for critical stability	1.684pu	1.810pu	2.137pu
Maximum angle swing	125.840^0	126.460^0	127.683^0
New operating angle	54.160^0	53.540^0	52.317^0

5.3 Three Phase fault with FACTS devices

Sending end and Midpoint fault with GCSC

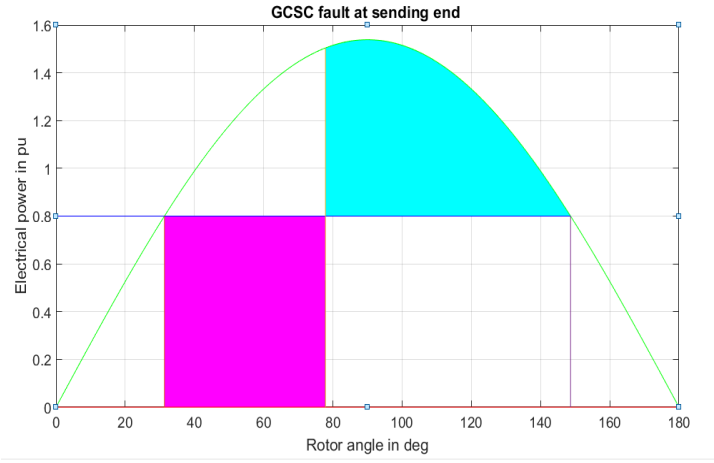

Fig.5: MATLAB plot of equal area criterion with GCSC for 3 phase fault at sending end

The transmitting end three-phase fault near the generator is present in the SMIB system taken into account by the GCSC. For a machine working at Pm = 0.8 pu, with an initial operating angle of 6.807 degrees, it is noted using the equal area criterion plotted in MATLAB as shown in Fig.5 that the fault should be cleared by the time shorter than the critical clearing time, tc = 0.219 sec. If a fault is fixed after a certain amount of time, the system loses synchronization with the infinite bus and becomes unstable. The maximum angle of swing at tc is the angle above which the rotor losses its synchronism which is equal to 154.612^0. If the

fault is not cleared before critical clearing angle 75.93 deg then the accelerating energy area is increased such that decelerating area cannot be greater than the accelerating energy area and therefore the rotor loses its synchronism with infinite bus and the machine becomes unstable.

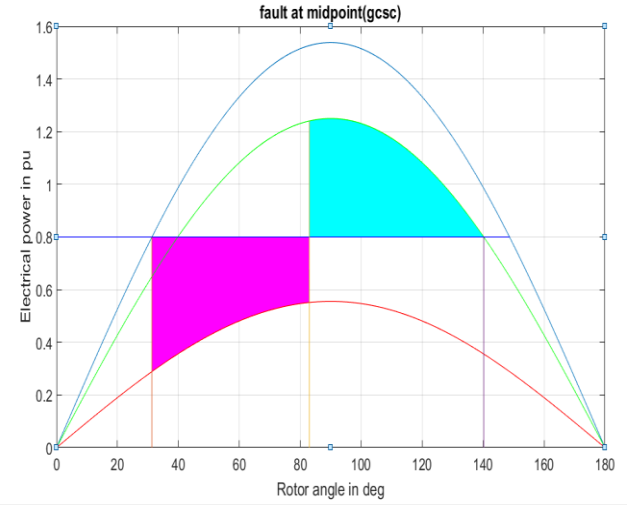

Fig.6: MATLAB plot of equal area criterion with GCSC for 3 phase fault at mid-point of transmission line

The SMIB system considered with GCSC is subjected to midpoint three phase faults between the generator and the infinite bus. Using the equal area criterion plotted in MATLAB as shown in Fig.6 it is observed that for a machine operating at Pm = 0.8 pu, with initial operating angle 6.807 degrees, the fault should be cleared within the rotor reaches the critical clearing angle 120.465 deg .

The system loses synchronism with the infinite bus and becomes unstable if the problem is fixed after the rotor has beyond the critical clearing angle. The critical clearing angle, which is equivalent to 120.465, has a maximum swing angle over which the rotor loses synchronism. The rotor loses synchronism with the infinite bus and the machine becomes unstable if the defect is not fixed before the critical clearing angle of 75.93, which causes the accelerating energy area to increase such that the decelerating area cannot be bigger than the accelerating energy area.

Sending end and Midpoint fault with TSSC

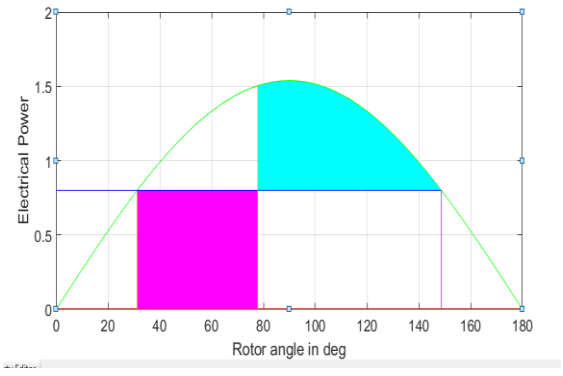

Fig.7: MATLAB plot of equal area criterion with TSSC for 3 phase fault at sending end

The SMIB system considered with TSSC is subjected to sending end three-phase fault near the generator. Using equal area criterion plotted in MATLAB as shown in Fig.7,it is observed that for a machine operating at Pm = 0.8 pu, with an initial operating angle 17.235 degrees, the fault should be cleared by the time less than critical clearing time, tc = 2.298 sec. If the fault is cleared after critical clearing time then the system losses its synchronism with the infinite bus and becomes unstable. The maximum angle of swing at tc is the angle above which the rotor

losses its synchronism which is equal to 162.765^0. If the fault is not cleared before critical clearing angle 101.684^0 then the accelerating energy area is increased such that decelerating area cannot be greater than the accelerating energy area and therefore the rotor loses its synchronism with the infinite bus and the machine becomes unstable.

Equal area criterion-Mid Point 3 phase fault--with TSSC connected

Three phase midpoint faults between the generator and the infinite bus are present in the SMIB system taken into account using GCSC. For a machine working at Pm=0.8 pu, with a starting operating angle of 17.235 degrees, it is noted using the equal area criterion plotted in MATLAB as shown in Fig.8 that the fault should be cleared before the rotor reaches the critical clearing angle of 141.13 deg. If the fault is cleared after the rotor exceeding the critical clearing angle then the system losses its synchronism with the infinite bus and becomes unstable. The maximum angle of swing at critical clearing angle is the angle above which rotor losses its synchronism which is equal to 162.71^0. If the fault is not cleared before critical clearing angle 146.21^0, then the accelerating energy area is increased such that decelerating area cannot be greater than the accelerating energy area and therefore the rotor loses its synchronism with infinite bus and the machine becomes unstable.

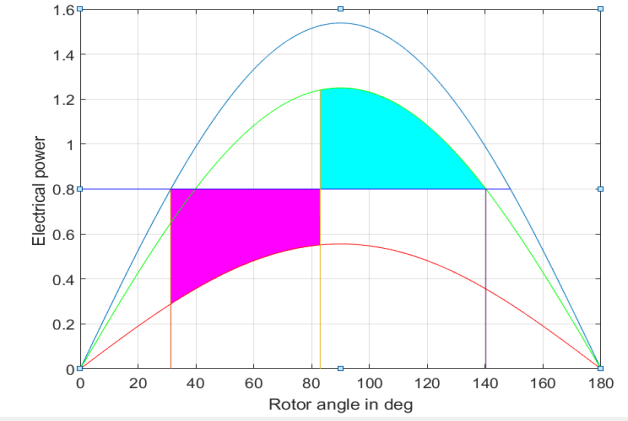

Fig.8: MATLAB plot of equal area criterion with TSSC for 3 phase fault at midpoint of transmission line

Table 3 Results obtained for Transient stability analysis (Three phase fault) with different FACTS devices

Device	Type of fault	Initial power angle	Maximum angle swing	Critical clearing angle	Critical clearing time
NO FACTS device	Sending end fault	22.665	157.345	90.99	0.397
	Midpoint fault	22.665	155.492	107.86	
GCSC	Sending end fault	6.807	154.612	75.938	0.419
	Midpoint fault	6.807	153.612	120.465	
TSSC	Sending end fault	17.235	162.765	101.684	0.498
	Midpoint fault	17.235	162.765	141.381	

5.4 Critical Clearing Time for Mid-Point Fault Using Swing Curve without FACTS

For mid-point fault the critical clearing time could not be found out using the equal area criterion, because of the nonlinear swing equation. To determine the crucial clearance time for mid-point fault, the nonlinear swing equation is therefore solved using the Runge-Kutta method. Plots of the swing curve are shown in Fig.9 for both the SMIB system with

and without the FACTS device. The input is the fault clearance time. The power angle in the swing curve increases without bounds and the system becomes unstable if the fault clearing time is longer than the critical clearance time. In contrast, when the power angle δ returns to the swing curve following the greatest swing, the curve returns after the maximum swing then the oscillations will subside and the system returns to the stable state.

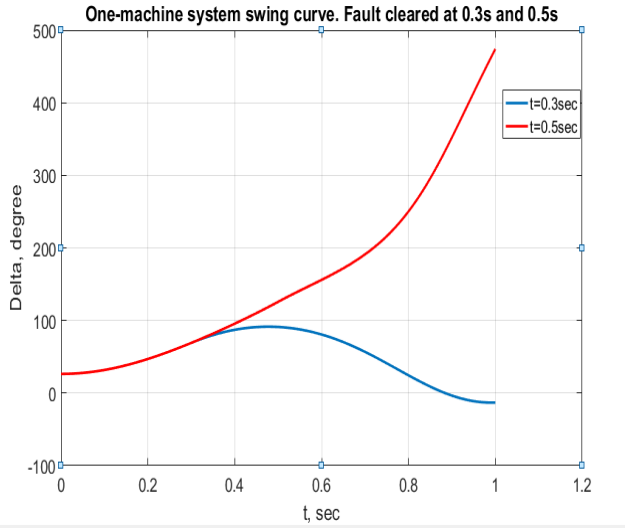

Fig.9: Swing curve without FACTS

The SMIB system considered is subjected to a midpoint fault between the generator and the infinite bus. The power angle, δ versus time called the swing curve is plotted using MATLAB as shown in Fig.9. The critical clearing angle was found to be equal to 107.869º for which the corresponding critical clearing time is 0.44 seconds. The graph shows that when the fault clearance time, tf is less than the critical clearing time, tc , the system returns back to a stable state and synchronizes with the infinite bus. Whereas when the fault clearing time tf is greater than the critical clearing time, the power angle, δ keeps on increasing beyond 180o , indicating that the system stability is lost with the infinite bus as it loses its synchronism.

Critical clearing time for mid-point fault using swing curve with FACTS

The SMIB system considered with GCSC is subjected to a midpoint fault between the generator and the infinite bus. The power angle, δ versus time called swing curve is plotted using Matla shown in Fig.10. It was found that the critical clearing angle is equal to 75.938o, and the critical clearing duration is 0.419seconds. The graph demonstrates that the system returns to a stable condition and synchronizes with the infinite bus when the fault clearing time, tf, is smaller than the critical clearing time, tc.

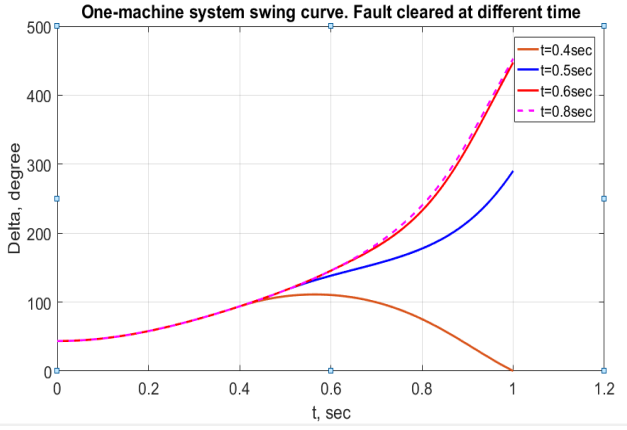

Fig.10: Swing curve with GCSC

Whereas when the fault clearing time tf is greater than the critical clearing time, the power angle, δ keeps on increasing beyond 180º, indicating that the system stability is lost with the infinite bus as it loses its synchronism.

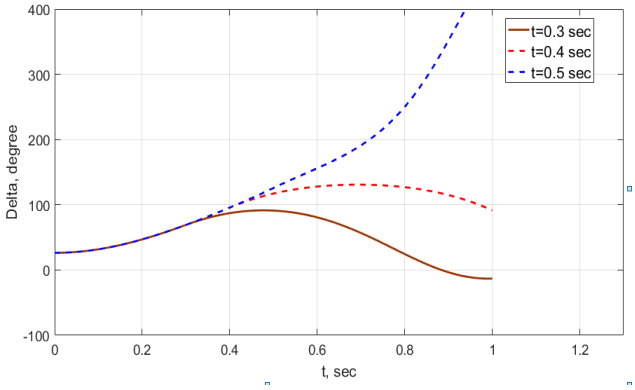

Fig.11: Swing curve with TSSC

The SMIB system considered is subjected to a midpoint fault between the generator and the infinite bus. The power angle, δ versus time called swing curve is plotted using MATLAB as shown in Fig.11. The critical clearing angle was found to be equal to 101.684 for which the corresponding critical clearing time is 0.498 seconds. The graph shows that when the fault clearance time, tf is less than the critical clearing time, tc , the system the system returns back to a stable state and synchronizes with the infinite bus. Whereas when the fault clearing time tf is greater than the critical clearing time, the power angle, δ keeps on increasing beyond 180º, indicating that the system stability is lost with the infinite bus as it loses its synchronism.

Table 4 Comparison of all FACTS devices for - Swing curve and critical clearing time

S. No	Device	Critical clearing angle	Critical clearing time
01	No facts device	107.869	0.392
02	GCSC	75.938	0.419
03	TSSC	101.684	0.496

From the Table 4 the inference drawn is the facts device which having higher critical clearing time which gives an better stability limit because system returns back to a stable state and synchronizes with the infinite bus. Hence TSSC is best FACTS device compared with GCSC.

6. CONCLUSION

A comparison of various FACTS devices, such as the GCSC and TSSC, is offered for improving small signal and transient stability. By computing the system matrix and its corresponding Eigen values, small signal stability is carried out using Eigen value analysis, and several implications for improving small signal stability are presented for various FACTS controllers. When several FACTS controllers are coupled to the SMIB system, the transient stability experiments are conducted using the equal area criterion. For the SMIB system controlled by FACTS, parameters like the critical clearing angle and critical clearing time are established. It is evident from the analysis that impedance base FACTS controllers are offering more stability. In contrast to alternative FACTS controllers, it is also obvious that TSSC offers greater stability. Small-signal stability studies of transient stability in small and transient stability studies the computation and analysis with respect to sending the end bus can only be made. That is the dynamic and fault analysis on sending end bus of the power system can only be performed. Whereas, the load side transmission system parameters cannot be computed and analyzed.

REFERENCES

[1] Goutham Govind Raju R., Subramaniam, N.P. 2011. Transient Stability Analysis Employing Equal Area Criterion, 228-233

[2] Songyan Wang, Jilai Yu, Wei Zhang,2018. Transient Stability Assessment Using Individual Machine Equal Area Criterion PART I: Unity Principle, 77065-77078

[3] Kameswari kandula , Murthy K.V.S.R. Improvement of First Swing Stability Limit By Using Facts Devices, International Journal of Engineering Research and Applications, 1(4), 1559-1564

[4] Mohammed Mynuddin, K. M. Roknuzzaman, Prodip Biswas , Mohammad Tanjimuddin, 2015 Stability Study of Power System, International Journal of Energy and Power Engineering, 4(2) 43-50.

[5] Anupriya Pathak 2020, A Review On Facts Devices In Power System For Stability Analysis, international Journal of Recent Advances in Multidisciplinary Research, 07(10)6320-6324,

[6] Arti Devi Patel, 2015. Comparison of Shunt Facts Devices for the Improvement of Transient Stability of Two Machine Power System using MATLAB Modeling IJSRD - International Journal for Scientific Research & Development, 3(10)944-949

[7] Abinash Singh and Balwinder Singh Surjan,September 2016. Comparative Study of FACTS Devices for Mitigation of Voltage Sag-Swell in Distribution System, Indian Journal of Science and Technology, 9(34)1-8

[8] Qurratul Ain, Emad Jamil, Salman Hameed & Kumail Hasan Naqvi, 2020. Effects of SSSC and TCSC for enhancement of power system stability under different fault disturbances, Australian Journal of Electrical and Electronics Engineering, 56-64

[9] Hadi Saadath, Dynamic of power system analysis, printice hall publication

[10] Arti Devi Patel 2015. Comparison of Shunt Facts Devices for the Improvement of Transient Stability of Two Machine Power System using MATLAB Modelling, International Journal for Scientific Research & Development, 3(10) 1-8

[11] Bhushan D. Deotale, Sudhir R. Paraskar, 2016. Transient Stability Improvement using Thyristor Switched Series Capacitor (TSSC) FACTS Device, IEEE Students Conference on Electrical, Electronics and Computer Science 1-6

[12] LIU Qing, Wang Zengping, Zheng Zhenhua, 2008. Study and Simulation of SSSC and TCSC Transient Control Performance, 1-6

[13] Abdollah Ahmadi , Foad H. Gandoman, Behnam Khaki , Adel M. Sharaf , Josep Pou, 2018 Comprehensive review of gate-controlled series capacitor and applications in electrical systems IET Generation, Transmission & Distribution, 1-8

[14] Aakib Majeed, Bilal Ahmad, Yuvraj Singh, 2019. Power System Stability, Efficiency and Controllability Improvement using Facts Devices, International Journal of Engineering Science and Computing, January 4307-4313

[15] Ram Prasath, P., Sakthi Nagaraj, M. K. N. M. 2020. Analysis of Power System Stability by using Facts Devices' International Journal of Recent Technology and Engineering, 9 (1) 2277-2287

[16] Sireesha., A. Naresh G. Vara Lakshmi, S. 2018. Comparison of FACTS Devices for Transient Stability Enhancement of Multi-machine Power System International Journal of Research and Analytical Reviews , 5 (3) 1-8

[17] Wibawa, B C., Prastiantono, A., Aryani, D R., Setiabudy R., Husnayain F. 2019. Transient stability improvement by FACTS devices: A Comparison between STATCOM and SSSC in an extra high voltage transmission system IOP Conf. Series: Materials Science and Engineering, 1 (2)1-8

[18] Saif, T. Fadhil, Ahmet, M. Vural 2019. Comparison of Dynamic Performances of TCSC, Statcom, SSSC on Inter-Area Oscillations 5th International Conference on Electrical and Electronics Engineering 1-8

All © 2022 are reserved by International Journal of Advanced Science and Engineering. This Journal is licensed under a Creative Commons Attribution-Non Commercial-ShareAlike 3.0 Unported License.